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QUANTITATIVE STUDIES ON INSHORE MARINE DIATOMS AND DINOFLAGELLATES OF SOUTHERN CALIFORNIA IN 1920

BY

WINFRED EMORY ALLEN

STYLARIOIDES PAPILLOSA SP. NOV., A NEW ANNELID FROM THE SAN DIEGO REGION

BY

CHRISTINE E. ESSENBERG

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN ZOOLOGY
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QUANTITATIVE STUDIES ON INSHORE MARINE DIATOMS AND DINOFLAGELLATES OF SOUTHERN CALIFORNIA IN 1920

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(Contribution from the Scripps Institution for Biological Research of the University of California)

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QUANTITATIVE STUDIES ON INSHORE MARINE DIATOMS AND DINOFLAGELLATES OF SOUTHERN CALIFORNIA IN 1920

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WINFRED EMORY ALLEN

INTRODUCTION

This paper is the second of a series of papers dealing with this subject, the first of which covered the work done in the last four months of 1919 at the pier belonging to the Scripps Institution for Biological Research of the University of California at La Jolla (Allen, 1922). The present report covers material similar to that described in the first paper. This material was taken by the same methods and equipment and handled and studied in a similar way. The only difference is that in this series a part of the material was obtained from another station (Pt. Hueneme) at the eastern end of Santa Barbara Channel about one hundred miles northwest from La Jolla, located in latitude 34° 08′ 38″ North and longitude 119° 12′ 40″ West; also, this material was taken by a pier employee (Mr. B. E. Garner) on six mornings of each week as he found opportunity in connection with his regular employment.

Since the work of this year was carried on in the same way as that described in the above mentioned report for 1919, it is assumed that preliminary discussion is unnecessary and that we may properly enter at once upon direct consideration of the material.

GENERAL DISCUSSION

Through the first eight months of 1920 collections were taken at intervals of twelve hours at the La Jolla pier. Since such a series cannot properly be compared with one taken at different intervals, this series may best be segregated and discussed first merely as a twelve-hour series. The morning catches can then be properly included in a separate discussion of the twenty-four-hour series taken at both stations.

The Twelve-Hour Series

Attention will here be limited to features peculiar to the twelve-hour series. These features are all connected with the question as to whether larger numbers of diatoms and dinoflagellates were taken in morning or in evening catches. This question has already received some attention (Allen, 1922).

Summaries now available for the twelve months from September 1, 1919, to September 1, 1920, show a rather marked difference in diatoms and dinoflagellates, the former being taken in larger numbers in morning catches, the latter in evening catches. This fact is best shown by comparing single catches with the two nearest, i.e., twelve hours earlier and twelve hours later. Thus, in the case of diatoms, in the twelve months, 146 morning catches were larger than the two nearest evening catches while only 62 evening catches were larger than the two nearest morning catches. But, in the case of dinoflagellates, only 86 morning catches were larger than the two evening catches while 135 evening catches were in excess of the two morning catches.

Similar differences appear when comparing catches with the last one preceding them. Thus, in the twelve months, each of 224 morning catches of diatoms exceeded that taken the evening before and only 136 of the evening catches exceeded those taken respectively the mornings before, while four were equal. But, in the case of dinoflagellates, only 163 of the morning catches exceeded those respectively of the preceding evenings, while 198 of the evening catches exceeded those respectively of the preceding mornings, four being equal.

Such numerical differences obviously suggest the possibility that diatoms generally tend to reproductive activity at night rather than in the daytime when their energies are occupied in photosynthesis. It also appears that dinoflagellates are not thus inclined. This difference in the groups strongly indicates that their characteristics are so different that they cannot properly be considered together as a photosynthetic assemblage. It also indicates the justice of Kofoid and Swezy's assertion (Kofoid and Swezy, 1921) that the holophytic aspect of the activities of dinoflagellates has been over-rated.

In addition to these points there are the repeated evidences that distribution of organisms in sea water is not uniform. There were very few days in the whole year in which catches twelve hours apart showed approximately the same numbers and these few days were all found to be in periods of very low production.

The Twenty-four-Hour Series

In working over the records of catches at both La Jolla and Pt. Hueneme it was found necessary to use some unit of time greater than the day and less than the month. In some ways five-day units seem to be most satisfactory, but they are not in common use and on account of omission of Sunday collecting at Pt. Hueneme this unit could not be applied. It was therefore decided to adopt the week as the standard unit in this kind of discussion. This unit is also desirable because of its use by our hydrographic workers and by the United States Weather Bureau.

Seasonal Variations in Numbers

One of the first questions to be raised concerning a series of catches running over a period of a year is that about seasonal variations, the more obvious of which may be expected to be variations in numbers and variations in species or representative forms. As to the first it is generally understood that maximum production occurs in the late spring or early summer and that there is also a rise of production in autumn after a decline in late summer. While our 1920 evidence does not contradict this view, it does modify it to a considerable extent, in that the numerical distribution is not thus limited at either station.

The most marked departure from this expectation is to be noted in the La Jolla series of diatom catches, graphically shown in figure 1 and recorded in the first column of table 1. Here on January 29 was begun a very remarkable increase of production which was well sustained for a period of eight weeks, after which the markedly productive periods, distributed in five groups, did not endure more than three weeks. In fact, the period of heaviest production, which came early in May, lasted only a little more than a week and the period of next heaviest production was largely confined to the last week of June and the first week of July. Evidently the moderate pulse of production occurring in September was the only one meeting ordinary expectations.

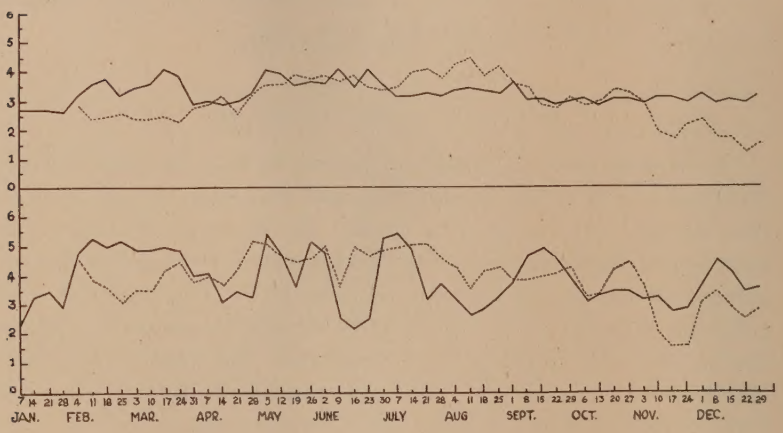

Fig. 1

Unfortunately the Pt. Hueneme series was not opened until February 1 and it may have missed most of a period of heavy production, a part of which is indicated in the case of diatoms for the week ending February 4 (fig. 1 and table 1). At any rate the heaviest production of the year occurred in the last week of April and the first week of May, a date also somewhat earlier than usually expected. The period of best sustained production was through most of June and July which is fairly near to expectation. There is, however, no marked pulse in autumn.

Since the numerical distribution of the dinoflagellates at the two stations was somewhat similar to that just described for the diatoms, it is not necessary to discuss them in detail. Figure 1 and table 1 give

the essential points. Note that the numbers of dinoflagellate cells are on the average smaller (usually much smaller) than the numbers of diatom cells throughout the year at both stations.

TABLE 1

DAILY AVERAGE NUMBERS OF CELLS PER LITER IN SEVEN DAY PERIODS THROUGH 1920

No. of week	For week ending		Diatoms		Dinoflagellates	
			La Jolla	Pt. Hueneme	La Jolla	Pt. Hueneme
1	January	7	231	.....	601	.....
2		14	2,510	.....	570	.....
3		21	3,412	.....	554	.....
4		28	1,000	.....	430	.....
5	February	4	67,853	45,760	1,913	800
6		11	200,301	8,712	4,900	307
7		18	105,852	4,619	6,898	389
8		25	161,255	1,259	1,669	448
9	March	3	81,570	3,557	3,345	309
10		10	99,648	3,815	4,192	266
11		17	110,014	18,451	12,942	344
12		24	94,858	33,543	8,347	245
13		31	10,183	6,357	965	789
14	April	7	13,162	11,584	1,056	864
15		14	1,346	5,070	987	1,760
16		21	3,837	20,755	1,138	464
17		28	2,436	161,299	2,168	2,416
18	May	5	364,723	130,851	13,045	4,528
19		12	65,408	52,756	10,997	4,176
20		19	4,823	31,672	4,217	8,600
21		26	185,253	45,269	5,582	7,178
22	June	2	67,522	123,120	4,202	9,296
23		9	407	6,032	15,157	6,035
24		16	183	122,100	3,911	8,475
25		23	320	58,716	15,490	3,221
26		30	232,867	86,091	4,185	2,752
27	July	7	341,851	104,328	1,774	3,781
28		14	85,416	128,819	1,641	10,503
29		21	1,751	142,445	2,290	14,840
30		28	6,893	41,630	1,774	7,746
31	August	4	1,742	23,136	2,602	24,195
32		11	617	4,107	3,750	35,691
33		18	878	17,507	2,560	8,861
34		25	2,286	24,667	2,121	16,589
35	September	1	6,991	8,088	5,557	6,303
36		8	55,832	8,913	1,497	3,611
37		15	102,219	11,619	1,271	816
38		22	43,173	15,179	958	691
39		29	8,436	20,987	1,099	1,357
40	October	6	1,739	2,446	1,367	904
41		13	2,811	3,019	843	1,021
42		20	3,226	20,369	1,271	2,736
43		27	3,393	38,837	1,374	2,195
44	November	3	1,989	5,984	1,179	1,029
45		10	2,183	133	1,870	110
46		17	706	47	1,613	61
47		24	921	41	1,147	171
48	December	1	6,020	1,365	2,343	265
49		8	42,427	3,816	1,057	75
50		15	17,982	1,175	1,337	67
51		22	3,973	401	1,125	22
52		29	4,039	907	2,165	40

Variations in Kinds of Organisms

It might be expected that with such clearly marked periodicity of production, especially as shown by diatoms at the La Jolla pier (fig. 1 and table 1), there would be prominent shifts in the specific characters of the diatom and dinoflagellate populations. But for this year at least such distinctions do not appear.

At the La Jolla pier there were eighteen weeks in 1920 in which production of diatoms might be said to be conspicuous (although not always heavy) and in these eighteen weeks only eight forms were for any week included in the three most numerous. One of these was the catchall assemblage called *Chaetoceras* sp. which was necessarily indefinite in application. Of the seven species segregated *Bacteriastrum varians* Lauder was second for two successive weeks; *Chaetoceras affine* Lauder was second for one week and third for four weeks; *Chaetoceras curvisetum* Cl. (including *Ch. debile* Cl.) was first for three weeks, second for two, and third for three weeks; *Chaetoceras scolopendra* Cl. was second once and third once; *Leptocylindrus danicus* Cl. was first for two successive weeks; *Nitzschia seriata* Cl. was third in nine weeks, second in four, and third in two weeks; and *Skeletonema costatum* Grev. was second in three and third in two weeks.

Omitting the indefinite group *Chaetoceras* sp., there were only three forms in conspicuous abundance (averaging more than 50,000 per liter for one or more weeks) at the La Jolla pier in 1920, viz., *Nitzschia seriata* Cl., *Chaetoceras curvisetum* Cl., and *Leptocylindrus danicus* Cl. The prominence of the last named was confined to the last two weeks in May. One or both of the other two species was conspicuous at all seasons. Such evidence does not indicate any great tendency of the diatom population to change in character from one season to another.

At Pt. Hueneme the evidence of such change is a little stronger. Six forms of the eight which appeared amongst the first three in one or more productive weeks were the same as at La Jolla. *Bacteriastrum varians* Lauder and *Leptocylindrus danicus* Cl. did not reach prominence, but *Thalassiosira baltica* Grun and *Eucampia zoodiacus* Ehr. did. The former was very prominent for two weeks at the end of April and beginning of May, and the latter was most prominent during the second week in July. Aside from *Chaetoceras*

sp. these two were, with *Nitzschia seriata* Cl. and *Chaetoceras curvisetum* Cl., the conspicuous forms at Pt. Hueneme.

So far as we know at present *Nitzschia seriata* Cl. and *Chaetoceras curvisetum* Cl. may constitute a fairly stable portion of the diatom population in the southern California region and forms such as *Bacteriastrum varians* Lauder, *Leptocylindrus danicus* Cl., *Eucampia zoodiacus* Ehr., and *Thalassiosira baltica* Grun may be more typically variable, or fluctuating or delicately responsive in character, and so more truly indicatory of the incidence and influence of changes in their environment.

Dinoflagellates showed general features of seasonal distribution of species essentially similar to those of diatoms. At La Jolla eight forms attained prominence in one or more of the productive periods sufficient to place them amongst the first three species in one or more weeks. One of the most prominent of these eight was a catchall assemblage called *Gymnodinium* sp. which may at times have included many other minute organisms. In that respect the group is even more unsatisfactory than *Chaetoceras* sp. Two of the other prominent forms, *Peridinium cerasus* Pauls. and *Peridinium minutum* Kof., were often indistinct and hence not satisfactorily identified. Several small species may have been recorded under those designations at one time or another.

Of the five prominent species identified with approximate accuracy, *Prorocentrum micans* Ehr. was decidedly the most persistent, reaching third place or better in nine out of the ten noticeably productive weeks. In addition to it *Ceratium furca* (Ehr.) Clap. u. Lach. and *Peridinium minutum Kof.* were notably abundant in one or more weeks.

At Pt. Hueneme fourteen weeks were relatively productive in which six forms, besides *Gymnodinium* sp., were amongst the three most abundant in one or more weeks. Of these only four reached numbers large enough (3000 per liter or more) to be considered distinctive. They were *Prorocentrum micans* Ehr., listed amongst the first three in all of the fourteen weeks; *Ceratium furca* (Ehr.) Clap. u. Lach. amongst the first three in four weeks; *Ceratium tripos* (O.F.M.) Nitzsch. amongst the first three in three weeks; and *Peridinium minutum* Kof. amongst the first three in seven weeks.

As in the case of diatoms it appears probable that one or two species are relatively stable in the region studied and that others are

more sensitive to environmental changes or less able to make their own way. If this be true, at both La Jolla and Pt. Hueneme *Prorocentrum micans* Ehr. is evidently the typically stable species and *Ceratium furca* (Ehr.) Clap. u. Lach. shows similar tendencies. For this particular year it is clear that dinoflagellates present even less evidence than diatoms that there is a regular seasonal sequence in species.

Species and Genera

Since I have already in former papers (Allen, 1921, 1922) designated the more common forms and discussed certain characteristics exhibited by them in this region it is scarcely necessary to include such details in this paper or any other until our observations have been carried over enough years and localities to make such discussion more nearly accurate instead of merely suggestive. We have in expectation a period of at least five years of pier collections in this series which we hope may give ground sufficient for a revised statement of details.

Note.—In accordance with the recent movement toward condensation of scientific matter detailed discussion has been almost entirely omitted from this paper and (still more important) 228 pages of tables have been omitted. No place of deposit of such tables has yet been designated so that it will be necessary for those desiring further information to write to the Director of the Scripps Institution at La Jolla, California.

SUMMARY AND CONCLUSION

1. It is certain from the excellent condition of the series from Pt. Hueneme that a trustworthy untrained man can do satisfactory work in plankton collecting by our measured water method.

2. As is shown in table 1 the average *number* of diatoms is much greater through most of the year than is the average number of dinoflagellates. The ratio at La Jolla was nearly 1/15 and at Pt. Hueneme nearly 1/8. Actual nutritive values of the two populations may have been somewhat similar.

3. As is shown in the discussion of morning and evening catches, the behavior of diatoms and dinoflagellates is not enough alike to warrant my former practice of discussing them together as a photosynthetic assemblage, since the morning catches of diatoms exceeded those of the evening while the evening catches of dinoflagellates exceeded those of the morning.

4. The studies of this year have yielded continued evidence that distribution of organisms in sea water is not uniform.

5. Seasonal variations in numbers at La Jolla did not closely accord with the probabilities mentioned by various observers since a period of sustained productivity came much earlier than might have been predicted in the case of both diatoms and dinoflagellates. There was also some indication of such departure at Pt. Hueneme.

6. At neither station was there much variation in the kinds of diatoms and dinoflagellates according to time of year. There was some suggestion of the possibility that two or three forms are relatively stable and constant and that one or two other forms may gain prominence through marked responsiveness to seasonal differences.

7. From my experience in the study of this series it is increasingly evident that we not only need long, continuous series of observations in as many localities as possible but that we greatly need enormous increase of such observations in many complementary and supplementary lines.

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STYLARIOIDES PAPILLOSA, SP. NOV., A NEW ANNELID FROM THE SAN DIEGO REGION

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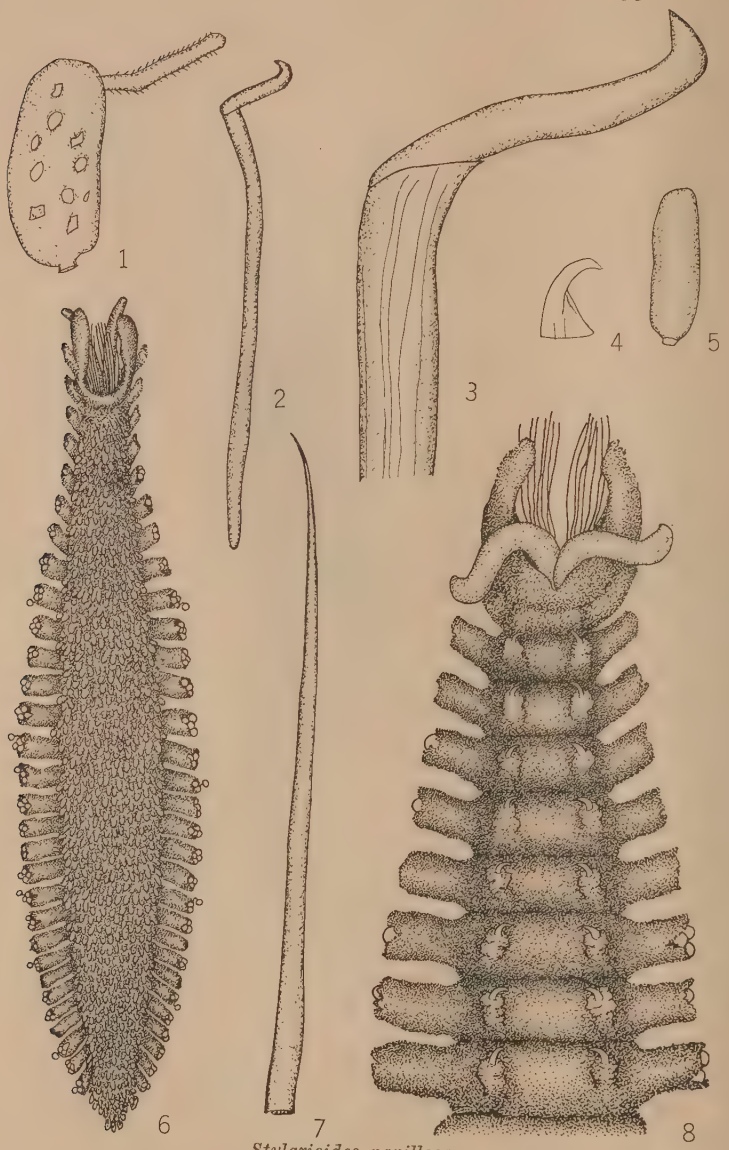
BY
CHRISTINE E. ESSENBERG

The polychaetous annelids of the family Stylarioidae are apparently rare in waters of the Pacific Coast of North America. The large annelid collection of the University of California at Berkeley does not contain any specimens of this family.

In the San Diego region, where shore collections are frequently made at low tide, a single specimen has thus far been found by the author and is evidently a new species which we designate *Stylarioides papillosa.*

This species is of a gray-brown color and is difficult to detect in mud where it lives, except by its wriggling motion. The body is about 70 mm. long, slightly flattened on the ventral side, tapers gradually toward both ends, and terminates bluntly at both. It has forty segments, which are visible only from the ventral and lateral surfaces. On the convex dorsal surface they are obscured by the abundance of long, finger-like projections (fig. 1). The mouth is surrounded by two long, green palps and by fourteen or more grass-green, long branchiae (figs. 1, 2). The parapodia are long in the living animal, with short papillae projecting even from their tips. In the preserved specimen the parapodia have contracted very much, so that they are hardly visible from the dorsal surface. There are two kinds of setae. The ventral setae, about two on each parapodium, are conspicuously large, compound, and hooked (figs. 3, 4, 6). The dorsal setae are long and slender. They are hardly visible in the living animal, being buried deeply in the parapodium (fig. 2). The dorsal projections, or villi, giving the animal a rough or spiny appearance, are of two kinds. Some are long, finger-shaped, attached to the body by a narrow neck (fig. 5); others are smooth and uniform in shape (fig. 8). These villi-like projections incline posteriad and between them are lodged grains of sand and mud, giving the animal the appearance of a moving piece of mud.



Stylarioides papillosa

Fig. 1. Villus. × 45.
Fig. 2. Ventral seta. × 45.
Fig. 3. Tip of ventral seta. × 320.
Fig. 4. Point of hook of ventral seta. × 320.
Fig. 5. Villus. × 20.
Fig. 6. Dorsal view. × 1.5.
Fig. 7. Dorsal seta. × 160.
Fig. 8. Ventral view of anterior portion. × 3.

Stylarioides papillosa has some resemblance to *S. plumosa* Chiaje (1828–1829) and to *S. flabellata* (McIntosh, 1915). It differs from both in various essential characteristics.

Its failure to be found in the many annelid collections from the Pacific Coast may be due to its remarkable adaptations and its protective coloring. Unless one makes a special effort to find it by pulling up the sea weeds under whose roots the animal lives, this polychaete would probably not be discovered.

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